Metamaterials: Making Optics from Scratch

Metamaterials are man-made, usually periodic structures. Under incident electromagnetic waves with wavelengths much larger than the constituent unit cells, these heterogeneous structures behave as homogeneous materials with effective electric permittivity ($\varepsilon$) and effective magnetic permeability ($\mu$). Given desired $\varepsilon$ and $\mu$, inverse problem of finding the corresponding unit cell underlies a wide variety of exotic things not possible with conventional optics such as perfect lens, perfect absorber, ultra-sensitive sensors, high-precision lithography, compact antennas, optical analog computers, antimagnets, quantum levitation, invisibility cloaks, and more. However, practical realization of all these applications demands (1) bulk (large volume) and low-cost fabrication methods. Additionally, the most fascinating applications driving the field such as imaging and lithography simultaneously require (2) negative index of refraction, (3) low-loss, and (4) full isotropy. To date, theoretical structures proposed to satisfy these requirements simultaneously at (5) optical ranges, have turned out to be too complex for two-dimensional lithography. (6) Tunability and (7) broad bandwidth are other aspects to extend the functionalities of metamaterial based devices. I will present our recent efforts related to these challenges in theory, design, and manufacturing of metamaterials. I will touch upon direct laser writing, plasmonics, and several applications of metamaterials including solar cells, antennas, analog quantum simulators, and superlens.